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INVESTIGATIONS OF PHOTOGRAPHIC GRAIN IN COHERENT AND INCOHERENT--ETC(U)
SEP 80 B J THOMPSON DAAG29-77-G-0014

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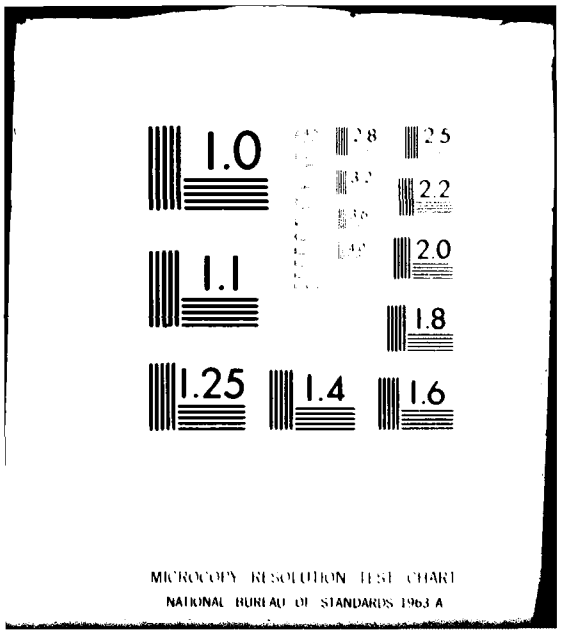
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The initial set of problems studied in this work consisted of:
(1) the comparison of the behaviour of photographic grain in coherent versus incoherent optical systems; (2) a more complete understanding of the signal dependence of grain in coherent and incoherent systems; and (3) the implications of the results of (1) and (2) in the fields of image evaluation and image processing.

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Investigations of Photographic Grain in Coherent and Incoherent Systems

B. J. Thompson

FINAL REPORT

Research Agreement No. DAAG29-77-G-0014

Department of the Army
U.S. Army Research Office

30 August 1980

Investigations of Photographic Grain in Coherent and Incoherent Systems

I. Problems Studied

The initial set of problems studied in this work consisted of:

(i) the comparison of the behaviour of photographic grain in coherent versus incoherent optical systems,

(ii) a more complete understanding of the signal dependence of grain in coherent and incoherent systems,

(iii) the implications of the results of (i) and (ii) in the fields of image evaluation and image processing.

These studies led naturally into some special problems in image processing with coherently recorded images. We concentrated on the practical aspects of image phase and wavefront reconstruction from measured intensity distributions in two defocused planes of a coherent optical system. Three methods of phase retrieval have been examined in detail: a direct method, the Misell or Gerchberg-Saxton algorithm, and a gradient search method.

Finally, a preliminary analysis of the Lau effect was carried out and the effect extended to develop a coherent (and partially coherent) Lau effect.

II. Summary of the Most Important Results

A. Photographic Grain Studies

1. Results indicate that the coherent analog spectrum gives the same granularity information about photographic materials that is usually generated by incoherent optical methods.

2. The first and second order statistics of the grain as they are manifested in the scattered light are the same in incoherent and coherent optical systems.

3. The signal-dependence of photographic grain has been demonstrated using uniform grain patches.

4. The effects of the nonstationarity of the first order statistics of the photographic grain and the use of spectral analysis techniques have been evaluated.

5. The signal-dependence of photographic grain has been shown to cause the traditional linear filter technique of image restoration to be ill-suited to the task of processing severely grain-degraded images.

B. Image Processing Studies

1. Three methods of phase retrieval using image intensities measured in two defocused planes have been examined in detail.

2. The direct method is non-iterative and potentially very rapid, but its recursive nature makes it extremely sensitive to errors and noise. The method was evaluated for simulated wavefronts under conditions of defocus error and noise. Sensitivity to round-off errors and noise precludes its use in any practical situation.

3. The iterative Misell algorithm has been studied with respect to its convergence properties under various conditions in image and wavefront reconstruction. The technique is reasonably tolerant of errors and noise and is thus useful for practical situations.

4. The gradient search technique attempts to minimize the error by adjusting the phases of each sample in the image. The method is reasonably tolerant of noise, but converges rather

slowly at points in the image having a low relative intensity. For best results, the required phase structure should be located in a part of the image having a large and almost uniform intensity.

5. The Lau effect has been investigated as a result of the propagation of partially coherent light. It is found that the fringe structure is dependent on the relationship between the grating separation and the periodicity of the complex degree of spatial coherence in the plane of the second grating. This provides a simple and elegant means of interpreting and extending the Lau effect.

III. Publications

Ph.D. Theses completed

1. "Theoretical and Experimental Studies on the Importance of Photographic Grain in Optical Systems", Scott A. Armstrong, May 1978.
2. "Phase Retrieval Techniques For Image and Wavefront Reconstruction", Richard H. Boucher, August 1980 (final oral thesis defense, September 12, 1980).

Ph.D. Theses in progress

1. "The Lau Effect: Theory, Experiments, and Applications", Ronald Sudol, Expected Spring 1981.
2. "Methods of Phase Retrieval and Phase Measurement", John Bortz, Expected Spring 1982.

Published Papers

1. "Comparison of Coherent and Incoherent Optical Spectrum Analysis Techniques in Image Evaluation", Scott A. Armstrong and Brian J. Thompson, in Data Extraction and Classification

from Film, R. D. Leighty, Ed., Proc. Soc. Photo-Opt. Instr. Eng. Vol. 117, p. 57-66, 1977.

2. "Comparison of Coherent and Incoherent Optical Spectrum Analysis Techniques in Image Evaluation", Scott A. Armstrong and Brian J. Thompson, Optical Eng. 17, 273-279, 1978.
3. "Investigations of Errors in Sample Auto-Covariance Functions and Their Corresponding Power Spectra", S. A. Armstrong and P. O. Gough, J. Opt. Soc. Amer. 68, 568-572, 1978.
4. "Studies of Photographic Grain in a Coherent Optical System: Signal-Dependence and Its Implications", Scott A. Armstrong in Airborne Reconnaissance III, J. H. Smith and T. C. Freitag, Eds., Proc. Soc. Photo-Opt. Instr. Eng. Vol. 137, p. 24-30, 1978.
5. "Convergence of Algorithms for Phase Retrieval from Two Defocused Intensity Distributions", R. H. Boucher, International Optical Computing Conference, Proc. Soc. Photo-Opt. Instr. Eng. Vol. 231, in press.
6. "An Explanation of the Lau Effect Based on Coherence Theory", R. Sudol and B. J. Thompson, Optics Comm. 31, 105-110, 1979.

Papers Submitted

1. "Fresnel Images, Coherence Theory, and the Lau Effect", R. Sudol, Proc. Soc. Photo-Opt. Instr. Eng. Vol. 240.
2. "The Lau Effect: Theory and Experiment", R. Sudol and B. J. Thompson, submitted to Applied Optics.
3. "Proof of the Necessity and Sufficiency of Conditions for Thin Phase Imagery", J. Bortz, submitted to Optica Acta.

Oral Papers at National and International Meetings

Papers number 1, 4, and 5 (above) were also presented orally at the meetings listed.

1. "Phase Retrieval Techniques for Image Processing in Coherent Systems", paper WP4, Optical Society of America Annual Meeting, Rochester, New York, October 8-12, 1979.
2. "Lau Effect Interpreted in the Context of the Theory of Partial Coherence", R. J. Sudol and B. J. Thompson, paper Th.E5, Optical Society of America Annual Meeting, Rochester, New York, October 8-12, 1979.
3. "Fresnel Images, Coherence Theory, and the Lau Effect", R. Sudol, Soc. Photo-Opt. Instr. Eng. 24th International Technical Symposium, July 1980.
4. "The Lau Effect", Gordon Conference on Coherent Optics, Ventura, California, June 1980.

IV. Participating Scientific Personnel

Principal Investigator:	B. J. Thompson	Dean, College of Engineering and Applied Science and Professor of Optics
	Peter Gough	Research Associate and Assistant Professor of Optics, part-time
	Scott A. Armstrong	Graduate Student Received Ph.D., 1978
	Richard Boucher	Graduate Student Ph.D. Final Exam Sept.12, 1980
	Ronald Sudol	Graduate Student Ph.D. expected Spring 1981
	John Bortz	Graduate Student Ph.D. expected Summer 1982